



Apiculture & Social Insects

Organic colony management practices are profitable for backyard beekeepers

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Management practice decisions are critical for maintaining honey bee, *Apis mellifera* L., colony health, and the profitability of beekeeping operations. These practices vary with the goals and the size of the beekeeping operations, particularly regarding the type and frequency of pest management strategies used. However, the impact of these practices on the profitability of the operations has rarely been quantified. Here, we compare the impact of 3 honey bee colony management systems (chemical-free, conventional, and organic) on the profitability of small stationary honey-and-bee-producing beekeeping operations. Over the 3 yr of the study, we found that the operations using the chemical-free management system had economic losses, while the operations using the conventional or organic management system generated revenue. Honey production and bee production were highest in the organic and conventional management systems resulting in profits that were 14 and 11 times higher than in the chemical-free management system, respectively. Numerically, honey production was 50% higher in operations using an organic management system than in operations using a conventional management system in year 3. Across systems, the first year of the beekeeping operation required the highest economic inputs, but their costs for the second and third years were significantly lower. Our results provide evidence that active parasitic mite control within colonies is critical for the profits of small-scale stationary beekeeping operations and that organic management is a profitable, long-term system for stationary beekeepers.

Keywords: honey bee, economics, honey production, beekeeping, managed pollinator

Introduction

Honey bees, *Apis mellifera* L., are domesticated insects managed by beekeepers for hive products (eg honey and wax) and pollination services. Beekeeping operations can be grouped based on their size as backyard (1 to 50 colonies), sideline (51 to 500 colonies), or commercial (>500 colonies) (Thoms et al. 2018). In the United States, commercial operations command the vast majority of attention from researchers and the media since they manage 85% to 95% of the honey bee colonies, but they only represent 1% to 2% of the beekeepers (Thoms et al. 2018). In contrast, most beekeepers (98% to 99%) are backyard or sideline beekeepers who manage less than 500 colonies (Thoms et al. 2018). Annual statistics about

colony management practices, colony losses, and productivity are, thus, heavily influenced by the participation of backyard and sideline beekeepers. Survey results show that, overall, beekeepers in the United States have experienced unsustainably elevated colony losses (over 30% of all colonies annually) since the beginning of the survey in 2007 (vanEngelsdorp et al. 2009, Bruckner et al. 2022). For backyard and sideline beekeepers, losses of just a few colonies can be the tipping point between making a profit or deciding to quit beekeeping altogether. Information about the costs of different management practices may impact the decision-making process of backyard and sideline beekeepers, but the impact of management practices on the economics of these beekeeping operations has rarely been studied (eg Kulhanek et al. 2021, Tubene et al. 2022).

Beekeepers' choices of colony management practices are highly predictive of honey bee colony health and overwintering survival (Thoms et al. 2018, El Agrebi et al. 2021, Kulhanek et al. 2021, Underwood et al. 2023). Among sideline and backyard beekeepers, management practices vary tremendously, particularly regarding the methods and frequency of pest control (Underwood et al. 2019, Steinhauer et al. 2021). Management decisions among these beekeepers are linked to the philosophy of the beekeeper toward the use of chemicals for pest control (primarily for *Varroa* mites) and the size of their operations (Underwood et al. 2019). There are 3 general types of approaches for managing pests and pathogens (Bruckner et al. 2023): First, operations with a chemical-free or treatment-free approach avoid the use of all nonbee-derived products for management, thus populations of *Varroa* mites are not controlled via miticide applications. Instead, the beekeeper relies on mite-resistant bee stocks or nonchemical practices for mite control. Second, operations with an organic approach avoid using antibiotics and synthetic miticides, and instead rely on organic acids, essential oils, and integrated pest management approaches for pest control following the National Organic Program's recommendations (Giacomini 2010, Behar 2019). The management system used here uses only chemicals that are allowed in the recommendations, but the hive products cannot be certified as organic, because of additional requirements for hive placement. Last, operations with a conventional approach allow the incorporation of any type of strategy for pest control, including synthetic chemicals and antibiotics. These categories are mainly defined by the types of *Varroa* mite treatment chemicals that are used.

While it has been demonstrated that miticide treatments are the most important management tool to support high colony survival and productivity in beekeeping operations (Thoms et al. 2018, Steinhauer et al. 2021, Underwood et al. 2023), no previous studies have estimated the costs, revenue, and profits of these different management systems. Previous economic analyses of commercial operations indicate that the profits of these businesses are generally low on a per colony basis and are based on an economy of scale. For example, an analysis of the net return per colony for operations of 1,000 colonies was only \$16.18 per colony per year (Champetier and Sumner 2019). Another study found that the income from almond pollination contracts for commercial beekeepers was lower than the cost of maintaining the colonies over the winter in preparation for pollination (Degrandi-Hoffman et al. 2019). As a result, the profits for these operations primarily come from honey sales.

Here, we evaluate how profits vary between stationary honey-producing operations managed under chemical-free, conventional, and organic management systems by comparing the costs of inputs and revenue from colony survival, honey production, and sales of bee splits. The beekeeping operations in this study each consisted of 12 stationary colonies that were studied for 3 yr. We investigated stationary operations because they are most common among backyard and sideline beekeepers and their primary sources of revenue are honey sales and occasional sales of bees (Tubene et al. 2022). We discuss the importance of incorporating optimal management practices to maximize honey production, bee sales, and profits for small and mid-size beekeeping operations.

Materials and Methods

Experimental Design

We analyzed the economics of 3 management systems (chemical-free, conventional, and organic) for a subset of colonies used in a previous study that investigated the impacts of management on

honey bee health (see Underwood et al. 2023). These 3 management approaches are commonly used in noncommercial stationary operations in the United States (Underwood et al. 2019). The protocols used in this study for each management system were developed through participatory science from a stakeholder group. We met with 30 beekeepers who represented the 3 management systems to elaborate on the detailed protocols used in this experiment. At their recommendations, the focal management systems varied in the type of equipment, treatments for *Varroa* mites, and types of emergency winter feed (Fig. 1).

In late April 2018, we purchased 144 honey bee packages (1.4 kg; 3 lb) from commercial producers in Georgia (USA), and established colonies on new frames in standard Langstroth 10-frame equipment. All colonies were re-queened in July 2018 with open-mated sister queens reared in Pennsylvania (USA) from a colony that had survived for 7 yr, despite not being treated for *Varroa* mites. These queens gave the colonies a genetic origin with an uncharacterized mechanism of mite resistance. Honey bee colonies were subsequently monitored for 3 yr (Year 1 = April to December 2018; Year 2 = January to December 2019; Year 3 = January to December 2020).

All colonies were located on 4 certified organic farms in Pennsylvania, USA (Fig. 2). Each farm hosted 36 colonies that were distributed equally among 3 apiaries. At the start, each apiary had 4 colonies per management system, totaling 12 colonies that were placed at the same location (Fig. 2). When colonies were set up in the apiaries, the left-right order of the 3 management systems varied to control for possible edge effects in the experiment. For this study, an operation was defined as the 12 colonies on a single farm that were managed under the same system, but were split evenly among the 3 apiaries on the farm (Fig. 2).

Colony Management

General Management

In the spring of year 1 (2018), we fed all colonies with Pro-Sweet (Mann Lake Ltd.) during the first 3 bi-weekly visits. Thereafter, we fed living colonies each fall, as needed, to reach a minimum weight of 27.2 kg (60 lb) of stored food (54.4 kg (120 lb) total hive weight). Winter feed was provided, when needed, as a candy board containing 3% protein for conventionally managed colonies, and dry sucrose for organically managed colonies. No chemical-free colonies needed to be fed in winter. All colonies had their entrances reduced to 10 cm year-round. Inserts were added under screens of conventionally managed colonies in October and remained in place until April each winter. See Fig. 1 for further details.

Apiary Visits

We assessed the colonies every 2 wk April to October throughout years 1 and 2 of the study (2018 and 2019), and every 3 wk in year 3 (2020) due to COVID-19 pandemic travel limitations. At each visit, we determined the queen's status, recorded the presence of diseases and pests, and added or removed boxes of frames, as needed. In the winter, colonies were visited once each month to assess the need for winter feed. If a colony was seen to be running out of stored food, additional carbohydrate feed was added, according to the protocol.

Mite Assessments and Treatments

Drone frames were in place from April through September each year in organically managed colonies (Fig. 1A). At each visit, capped drone brood was scraped from the drone frames in organically managed colonies as a mite removal strategy. Once every month, we measured

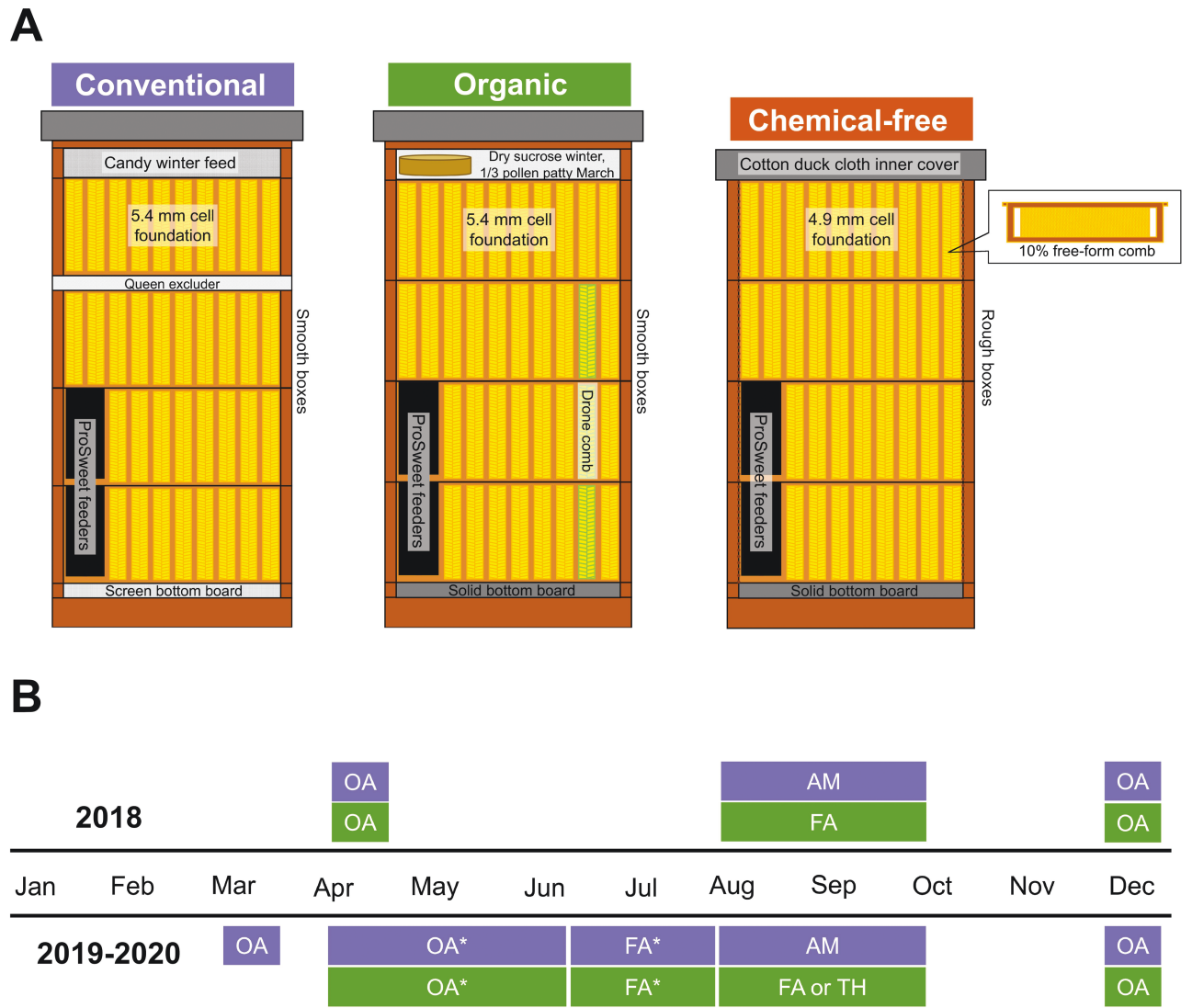


Fig. 1. Details of 3 honey bee colony management systems (modified from Underwood et al. 2023). A) Equipment used for each management system and B) timeline of treatment application. A cross-sectional view of each hive shows the equipment utilized in each management system. The miticide treatment timeline shows the different types of treatment used, such as oxalic acid (OA), amitraz (AM), formic acid (FA), or thymol (TH), during 2018 (year 1) and 2019 to 2020 (years 2 and 3) for colonies in conventional (blue), organic (green), and chemical-free (orange) management systems. See Underwood et al. (2023) for complete management details. *Mite treatments were applied to all colonies belonging to the same management system in a specific apiary when one or more colonies reached a mite population above 1 mite per 100 bees. In the fall, all colonies in the conventional and organic systems were treated regardless of their mite loads. "Figure modified from Underwood et al. 2023 (CC BY 4.0 <https://creativecommons.org/licenses/by/4.0/>)."

the population of parasitic *Varroa* mites by washing approximately 300 bees (118 ml; ½ cup) in alcohol following a standard procedure (Dietemann et al. 2013). We counted mites on-site after shaking the bees vigorously for 1 min to release mites attached to the bees' bodies and pouring the mites and alcohol through a strainer. If a single colony in the conventional or organic system was above a threshold of 1 mite per 100 bees, all of the colonies in that system in that apiary were treated with a miticide (see Fig. 1B for chemical treatment type by month).

Operational Costs

Operational costs included the initial purchase of honey bees, and subsequent inputs from mite treatments and feed needed in live colonies using advertised prices from Mann Lake Ltd. (<https://www.mannlakeltd.com/> accessed 4 June 2020; Table 1). Additional items, such as disposable gloves and specialized devices required for the

treatments were added to the cost of treatment and spread across all colonies. We determined winter feed costs based on the cost of commercial candy boards and granulated sugar in June 2020. We excluded the upfront costs of hive equipment, as they were the same for all 3 management systems. In addition, we excluded labor and travel costs from the calculations, because each beekeeper works at a different pace and travels different distances from their home. These are all personal expenses that beekeepers must calculate for themselves. Costs were adjusted each year for inflation, using numbers from the US Bureau of Labor Statistics' Consumer Price Index.

Revenue and Profits

We removed and extracted honey each July in each year of the study. To quantify the amount of honey produced per colony, each box was weighed before and after we extracted honey. No additional

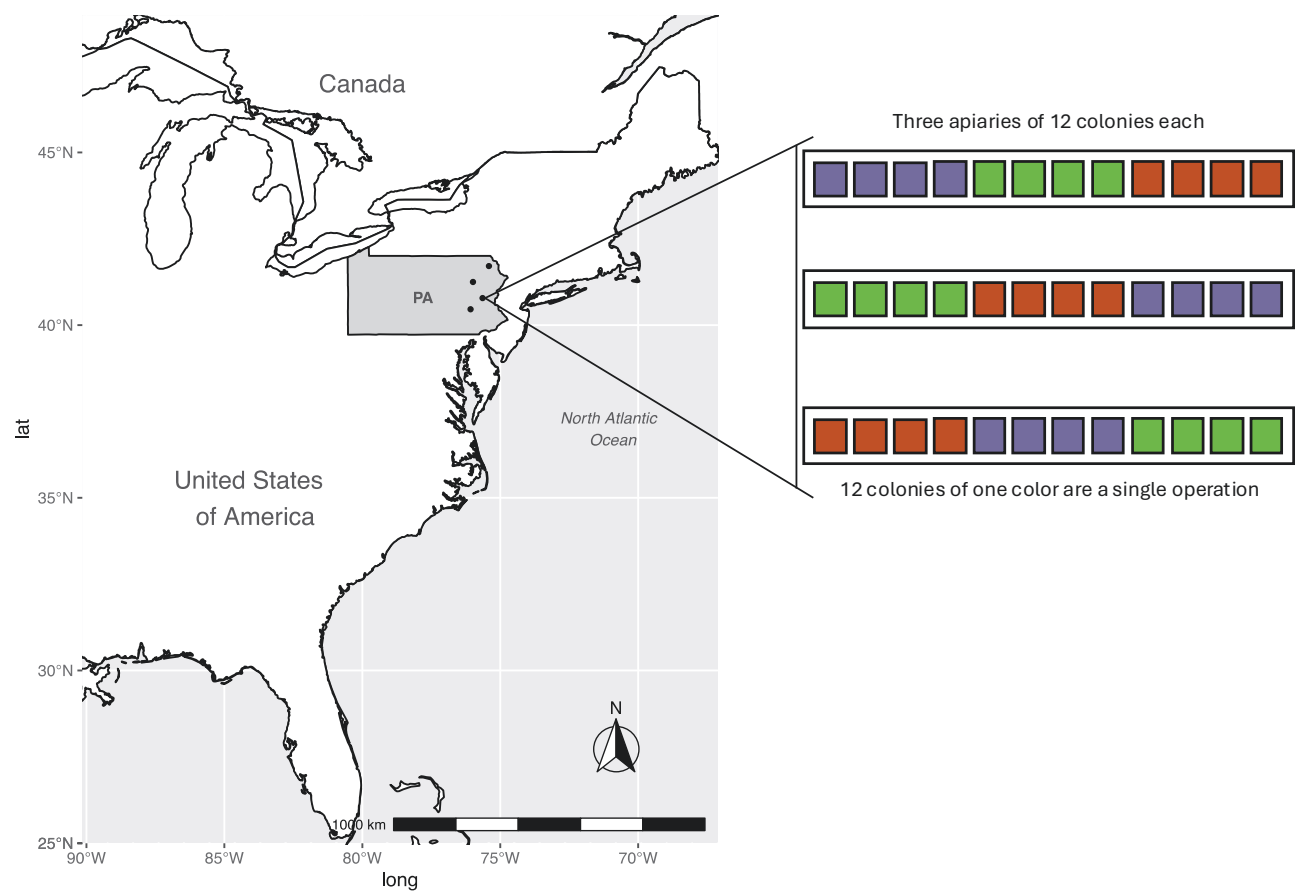


Fig. 2. Map of the state of Pennsylvania, USA, indicating the location of four farms where 144 honey bee colonies were kept for the duration of the study. At each farm (see callout), colonies from chemical-free, conventional, and organic operations were distributed across 3 apiaries.

Table 1. A list of the items and their associated costs/revenue (USD based on 2020 listings), including feed, treatments, and sources of revenue. These items were tracked for each colony in this study

Item	
Bees	
Bee package	Cost per each \$100.00
Feed	
Pro-Sweet (gallon)	\$14.00
Granulated sugar (lb)	\$0.50
Candy board (15 lb)	\$15.00
Ultrabee pollen patty (½ patty)	\$1.19
Mite treatment	
Formic Pro (2 strips); formic acid	\$5.20
Apivar (4 strips); amitraz	\$10.20
Apiguard (2 sachets); thymol	\$7.40
Oxalic acid (vapor, 1 g)	\$0.89
Revenue	
Honey (lb)	Revenue per each \$4.50
Split (nucleus colony) sold	\$165.00

bee packages or nucs were purchased after the first year of the study (spring 2018). In spring 2019 and 2020 (years 2 and 3), we used surviving colonies as a source of new colonies via splitting to replace those that had perished over the winter. It is a standard practice to split robust colonies to generate additional colonies by relocating the queen, along with 3 frames containing brood, and 2 frames

containing resources, into a new set of hive equipment. These new colonies are generally used by beekeepers to replace dead colonies from the winter or for sales (as packages or nucs) to increase revenue. When the initiation of swarming was evident, we split the colony, allowing the old queen to stay in one of the colonies and the development of a new queen in the other resulting colony. Thus, there were no costs associated with purchasing new queens in this study. New colonies (splits) that resulted in an increase in the target of 12 colonies per operation were sold as surplus and represented an additional source of revenue (Table 1). We tracked each operation’s profits over time, which was measured as the revenue from each operation minus its operational costs.

Statistical Analysis

To estimate economic profits per operation, the costs and revenues were calculated for each colony and summed to calculate the net profit or loss. These estimates were calculated per year adjusting for inflation.

To test the effect of the management system on economic variables, we fit ANOVAs using the ‘aov’ function with management system (a 3-level factor) as the predictor variable using R version 4.3.0. We first summed values across colonies per operation to obtain one value per management system per operation. Then, we fit models with cost, revenue, and profit as response variables followed by pairwise multiple comparisons with the “TukeyHSD” function. To test for the effects of management system, year, and their interaction on economic variables, we fit ANOVA’s with

management system (3-level factor), year (3-level factor), and the interaction between the 2. To test for differences in colony survival we fit an ANOVA with management system as predictor and the total number of colonies alive at the end of the experiment as the response variable.

Results

Profits

The operations using the chemical-free management system showed an economic loss, largely due to the relatively low colony survival, while the operations using the conventional or organic management system showed profits (Fig. 3, Table 2). For net profits, there was a significant year $\times$ management interaction (Table 2). In 2018 and 2019, profits were not different among management systems (Tukey HSD, $P > 0.9$). However, in 2020, profits in operations using a chemical-free management system were significantly different from those using a conventional or organic management system (Tukey HSD, $P < 0.02$; Fig. 3). In 2020, we recorded an average loss of \$1,648 in each 12-colony operation using the chemical-free management system, and gains of \$231 and \$1,483 per 12-colony operation using the conventional and organic management systems, respectively (Fig. 3).

Colony Survival

Colony survival was significantly higher in the conventional and organic management systems than in the chemical-free system

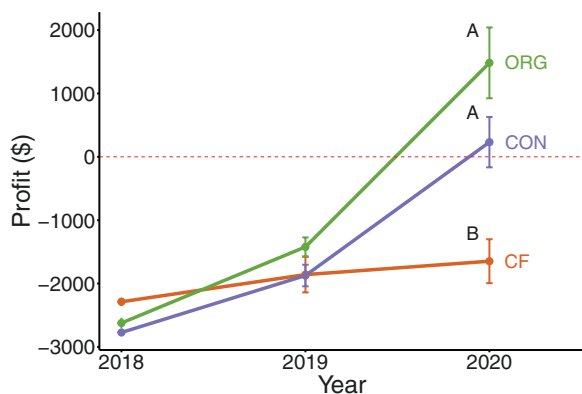


Figure 3. Mean ($\pm$ SE) net profit (total revenue minus costs) per operation ($N=4$) of 12 honey bee colonies using chemical-free (CF), conventional (CON), or organic (ORG) management systems over 3 seasons. Points with different letters are significantly different from each other (Tukey HSD, $P < 0.05$). Costs of equipment, travel, and labor are not included.

($F = 36.6$, $df = 2,9$, $P < 0.001$; Fig. 4). Colonies in the chemical-free management system experienced low survival with operations dropping from 12 to an average of only 2 colonies per operation after 3 yr (Fig. 4). In contrast, the colonies in both the conventional and organic management systems experienced high survival that resulted in a large number of colonies that could be split in the spring. Thus, the operation size was maintained close to 12 colonies per operation with conventional averaging 10 colonies and organic having 11.25 colonies after 3 yr (Fig. 4).

Operational Costs and Revenue

Operational costs differed across management systems and years, but there was not a significant interaction between year and management system (Table 2). The first year resulted in the highest costs, as the colonies were established at approximately \$2,475 for 12 chemical-free colonies, \$2,992 for 12 conventional colonies, and \$2,763 for 12 organic colonies in 2018 (Fig. 5A, Table 2). These differences in establishment costs across the management systems solely reflect differences in costs of feed and treatment. The costs for the second and third years were significantly lower, staying under \$400 for all management systems (Fig. 5A). Across all years, costs were significantly greater in colonies kept using a conventional management system than in those in the chemical-free system (Tukey HSD, $P < 0.02$). In 2019, colonies in the organic management system showed a greater total cost than those in the chemical-free system (Tukey HSD, $P = 0.03$), but they did not differ significantly in 2018 and 2020 (Fig. 5A; Table 2). When costs are broken down, the largest cost during the first year was associated with bee purchases and feed, which exceeded the cost of treatments for *Varroa* mites (2018; Fig. 6). In subsequent years, the largest expense was supplemental feed across all treatments (Pro-Sweet, candy boards, and sugar; Fig. 6).

Annual revenue increased over time, and the effect of the management system on revenue varied across years (Table 2, Fig. 5B). During the first year, there was overall low revenue (less than \$200 per operation) and was not different among management systems (Tukey, $P > 0.9$; Fig. 5B). In year 2, operations using an organic management system saw revenue increase to \$1,699 and conventional to \$1,410, but these did not differ significantly from revenue for the chemical-free management system of \$450 (Tukey HSD, $P > 0.09$; Fig. 5B). By year 3, revenue for operations using a chemical-free management system dropped to \$222, while revenue for operations using conventional and organic systems rose to \$2,516 and \$3,219, respectively, both significantly higher than the chemical-free system (Tukey HSD, $P < 0.001$; Fig. 5B). In all years, revenue for operations using organic and conventional management systems did not differ significantly (Tukey HSD, $P < 0.3$). The majority of revenue came from honey sales, which increased each year in organic and

Table 2. ANOVA results for models testing the effects of management system, year, and their interaction on cumulative profit, cost, and revenue

Variable	Factor	<i>F</i>	df	<i>P</i>
Profit	Management	10.77	2,27	<0.001
	Year	63.93	2,27	<0.001
	Management $\times$ Year	10.64	4,27	<0.001
Cost	Management	32.04	2,27	<0.001
	Year	1069.46	2,27	<0.001
	Management $\times$ Year	0.78	4,27	0.546
Revenue	Management	19.74	2,27	<0.001
	Year	29.75	2,27	<0.001
	Management $\times$ Year	7.65	4,27	<0.001

conventional operations (Fig. 7; Table 3). In 2020, colony splits also were a source of revenue bringing in over \$1,000 in both organic and conventional operations (Fig. 7).

Discussion

Our replicated experiment testing 3 different honey bee colony management systems found that chemical-free management was highly unprofitable while both organic and conventional management resulted in net profit after 3 yr. Profit differences are explained by management system-specific colony survival rates that result in different quantities of honey produced and nucleus colonies (splits) sold. We found that stationary sideline beekeeping operations operate at a loss under a chemical-free management system. In contrast,

operations in the organic management system have the most profit (Fig. 3).

Despite the overall trend in similar costs across management systems during the first year, the chemical-free system had lower operational costs than the organic and conventional management systems in subsequent years. The low costs of chemical-free operations were due to high colony mortality in this system, which resulted in fewer colonies that needed to be fed (Fig. 4). Treatments of *Varroa* mites were only a small part of year 1 expenses, making up only 3% to 5% of all costs in conventional and organic management systems. In subsequent years, when the cost of bees was zero and colonies were well established, costs were split between feeding and treatments. In general, if chemical treatments were used, they made up about a third of the operational costs.

The highest cost across all management systems was the initial investment in purchasing and feeding bees (Fig. 6). For feed, we used Pro-Sweet, as needed, for all colonies in the spring and fall, as well as candy boards and dry sucrose for the conventional and organic systems, respectively, in the winter. The cost of feeding during the first year was more than half of all expenses. The liquid feed, Pro-Sweet, is a thick honey-like 77% inverted sugar syrup (Mann Lake Ltd.). While this product is expensive, it does not require labor costs for mixing syrup, can be stored for a long time without fermenting or growing mold, and requires little processing by bees. We could have reduced feeding costs by mixing our own sucrose syrup, as is common among beekeepers in the United States. However, the labor costs associated with mixing, plus the lack of safe storage made this unsuitable for this study.

Regardless of the differences in costs, the profitability of the beekeeping operations was overwhelmingly determined by colony survival rates, which were highest in the organic and conventional systems (Fig. 5; Underwood et al. 2023). These results are in agreement with previous studies investigating the effect of management on colony survival (Thoms et al. 2018, Haber et al. 2019, Sperandio et al. 2019, Kulhanek et al. 2021). Despite the use of queens descended from a *Varroa* mite-resistant colony, only an average of 5 out of 12 colonies remained in the operations using a chemical-free management system after the first winter (by April 2019), and only an

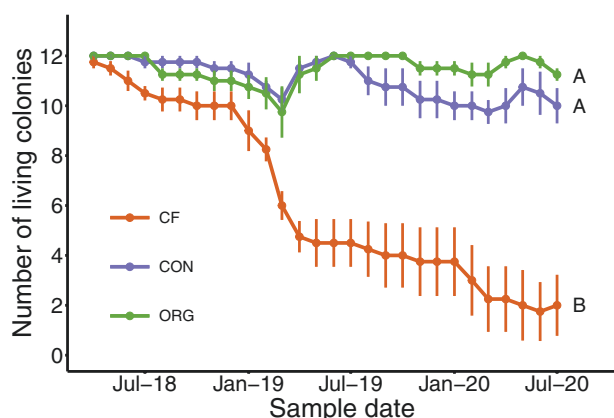


Fig. 4. Mean number of living colonies in each operation ($N=4$ operations per management system) $\pm$ SE over the duration of the study. The target number of colonies for each management system (operation) was 12 colonies. Colonies were managed using chemical-free (CF), conventional (CON), or organic (ORG) management systems over 3 seasons. Letters indicate significant differences (Tukey HSD, $P < 0.05$) for comparisons among management systems of the number of colonies surviving at the end of the experiment.

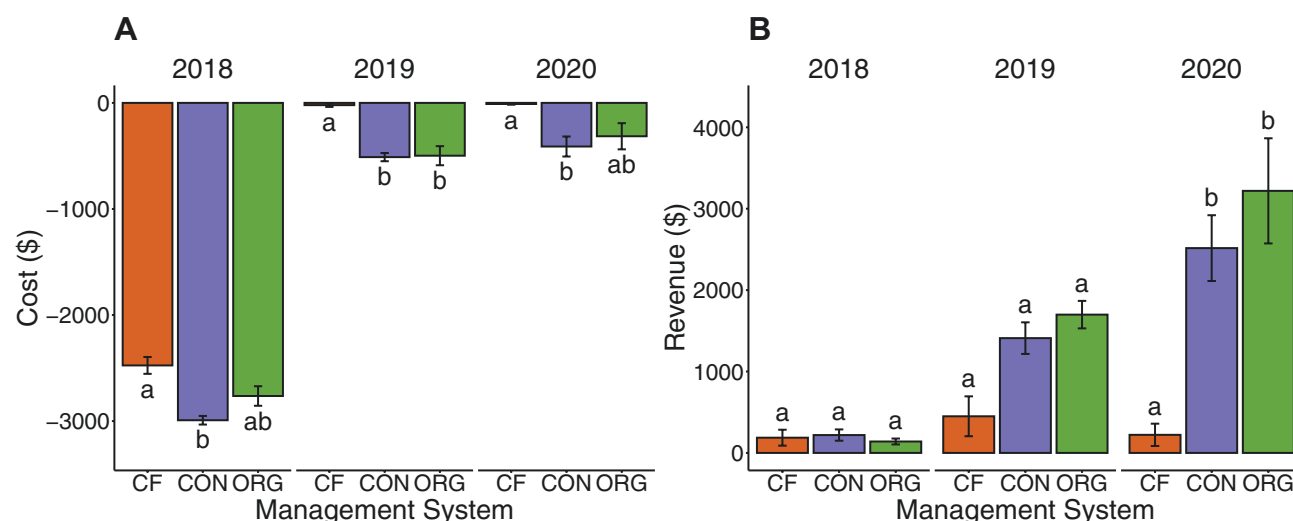


Fig. 5. A) Operational cost and B) revenue summaries within beekeeping operations varied across years and management systems. Each plot shows summed costs and revenue across operations of 12 colonies using chemical-free (CF), conventional (CON), or organic (ORG) management systems in each year of the 3-year study. Costs of equipment, travel, and labor were not included. Letters indicate significant differences (Tukey HSD, $P < 0.05$) for comparisons among management systems within each year.

average of 2 remained after the second winter (by April 2020; Fig. 4). Because mortality in the chemical-free management system was consistently high, it was not possible to maintain 12 colonies per operation at any time during the study. In contrast, both the conventional and organic systems exhibited high overwintering survival (approx. 85%) allowing the replacement of colonies and the maintenance of an average of 10 to 11 colonies per operation.

Revenue differences resulted from variations in the amount of honey produced and the number of splits (nucleus colonies) sold from colonies in operations under each management system. Because wax production is highly energetically costly for the colony when they are becoming established (see review by Hepburn et al. 2014, chapter 11), honey production is expected to be lower in years 1 and 2. Thus, honey production during year 3 is likely indicative of production in future years, as drawn comb is reused. Thus, if we use the costs and revenue from year 3 as predicted amounts for future years, we see the profits continue to diverge. Operations using a chemical-free management system were projected to still be at a loss of about \$1,000 after an additional 3 years (in 2023), while those using a conventional and organic management system had projected net profits of around \$6,000 and \$10,000, respectively.

We used a systems approach that varied in several aspects of management, so it is not possible to pinpoint the specific cause of differences in performance. When comparing organic and conventional to chemical-free operations, it is clear that *Varroa* mite management was the most critical aspect of management in the overwintering survival and productivity of these systems (see Underwood et al. 2023). Thus, the extreme colony losses in the chemical-free system drove the financial losses in these operations. Numerically, honey

production was 50% higher in organic operations than in conventional ones in year 3. These 2 systems shared several aspects of management: both systems utilized Pro-Sweet (Mann Lake Ltd.) as its supplemental feed, colonies were split when swarming was initiated, general management was performed with the same timing, and colonies were kept side-by-side in the same locations. The main differences between the 2 systems are that colonies in the conventional system had screened bottom boards, queen excluders, and were treated with synthetic miticides (amitraz) every fall. Some experimental studies have concluded that the use of queen excluders and the application of amitraz can reduce honey production (Rusig et al. 2002, Ilyasov et al. 2021). However, whether these 2 specific management practices negatively impact honey production in stationary honey bee colonies needs further investigation. Additionally, the use of drone brood removal as a mite mitigation practice was expected to decrease the production of honey by the colonies in the organic management system, as drone production is energetically costly (Seeley 2002). However, that was not seen in this study.

Overall, our results indicate that mite treatments are essential for the profitability of stationary beekeeping operations. When untreated colonies exceed treatment thresholds for *Varroa* mites, there is reduced honey production and lower winter survival compared with treated colonies (Currie and Gatten 2006, Underwood et al. 2023). Untreated colonies also exhibit reduced brood area and population size resulting in lower population growth (Ostermann and Currie 2004). Despite higher inputs associated with the purchase and applications of miticides, these costs are compensated for by significantly higher honey production, colony strength, and overwintering survival. Thus, with proper management, stationary

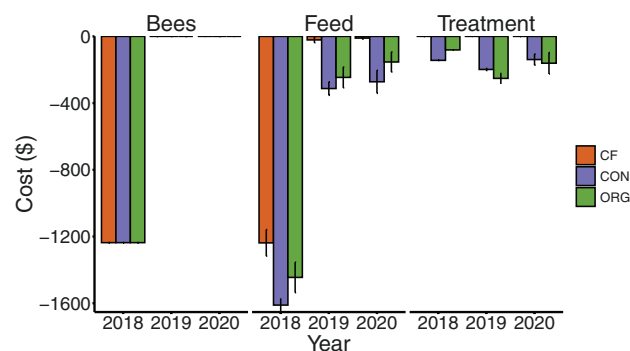


Fig. 6. Operational cost per 12-colony operation ($\pm$ SE) using chemical-free (CF), conventional (CON), or organic (ORG) management systems in each year of the 3-year study broken down by source. Costs of equipment, travel, and labor were not included.

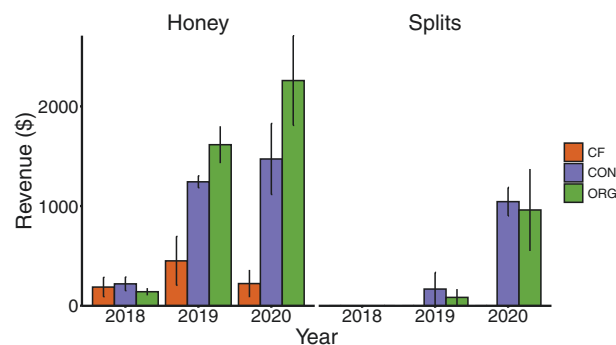


Fig. 7. Revenue per 12-colony operation ($\pm$ SE) using chemical-free (CF), conventional (CON), or organic (ORG) management systems in each year of the 3-year study broken down by source.

Table 3. The mean number of splits and quantity of honey per operation using chemical-free (CF), conventional (CON), or organic (ORG) management systems over 3 seasons

Trt	Year	No. splits	Honey (kg)	Honey (lb)
CF	2018	0.0	18.6	41.1
CON		0.0	21.9	48.2
ORG		0.0	14.0	30.8
CF	2019	0.0	44.8	98.8
CON		1.0	123.8	272.9
ORG		0.5	160.8	354.6
CF	2020	0.0	22.4	49.4
CON		6.3	148.4	327.1
ORG		5.8	227.7	502.0

backyard beekeeping operations can be profitable and sustainable. Using a combination of organic miticides and no queen excluders, organic operations overwintered successfully and produced high quantities of honey; 19 kg (42 lb) at an approximate value of \$189 per colony per year. We emphasize the need for applied research that generates recommendations for management practices that will help maximize profits for small and mid-size beekeeping operations.

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Author contributions

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